RECOVERY OF VISUAL ACUITY AFTER RETINAL DETACHMENT INVOLVING THE MACULA*

BY *Thomas C. Burton,* MD

INTRODUCTION

INTUITIVELY, PERHAPS, MORE THAN BY ANY OTHER METHOD, OPHTHALMOLOGISTS have thought that prompt surgery for retinal detachment would provide optimal visual recovery. It has been long observed, and more recently confirmed, that visual results are best when the macula has not become involved in the detachment process.[1-5] Unfortunately, in most large retinal detachment series the macula is involved about 75% of the time, a figure which has changed little over a period of many years.[6-11] Predetachment or early detachment symptoms obviously are not alerting patients adequately, or often their physicians, to the urgent need for thorough retinal evaluations.

Notwithstanding dramatic improvements in diagnostic and therapeutic techniques, functional recovery of the reattached retina has remained distressingly poor, with only about 40% of cases achieving 20/50 acuity or better.[2,6-9,12,13] Comparisons of visual results in large detachment populations several years apart, even from the same institution, fail to demonstrate improvement expected with refined techniques.[2,3,8] However, this observation does not account for attempts to operate on detachments of increasing complexity. Now, of course, cases, which a few years ago would have been considered inoperable, are being restored anatomically. On the other hand, the functional results in this class of detachments are very poor, tending to reduce the average visual recovery.

Unquestionably, the preoperative visual acuity provides the best prognostic index of anatomic success rates and final visual recovery.[5,6,13-17] A preoperative acuity of 20/20 to 20/50 implies a limited detachment with the macula spared or only flatly detached. As a consequence of pre-existing ocular pathology, not every detachment with macular sparing presents with good visual acuity.[5,15]

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Similar appearing detachments have widespread variations in final visual acuity.[18] Some authors believe that functional recovery is governed largely by factors beyond the influence of the retinal surgeon.[2,3] Kaufman[19] determined that 85% of variation in visual acuity was explained by nine factors, only one of which (duration of detachment) might be manipulated. Similarly, Burton and Lambert[13] isolated at least 22 factors (including age of patient, presenting visual acuity, type of detachment, pre-retinal membrane formation, vitreous membranes, macular cyst or hole, senile cataract, or history of glaucoma) none of which could be altered readily.

Tani et al[6] found 14 factors related to favorable functional results, the most important of which were preoperative acuities of 20/50 or better, less than total detachments, anterior tears, operative technique, and absence of the following: giant retinal tears, preoperative ocular hypotony, and untreated ocular hypertension.

Over the past several years there has been renewed interest in the study of functional recovery in retinal detachments involving the macula. The evidence concerning the importance of duration of macular detachment is conflicting. Important, if not critical, durations of macular detachment, after which the prognosis for visual recovery becomes worse, have been estimated at one week (Kreissig,[10] Davies[20]) two weeks (Hudson,[7] Marquez[21]), one month (Tani et al,[6] Charamis and Theodossiadis,[11] Davidorf et al[22]) and two months (Norton,[2] Grupposo,[15] Jay,[18] Cleary and Leaver[23,24]). Gundry and Davies[25,26] have indicated there is a progressive decline in recovery from day one onward, while Hughes[27] stated there seemed to be no influence on final vision as long as the retina had not been detached longer than six months.

Such inconsistent information tends to produce casual attitudes about the urgency of managing detachments which involve the macula. Surgical delays of several days, often desirable for a variety of reasons, might seem more acceptable. It appears prudent, however, on the basis of current information, to encourage prompt surgery rather than permit unnecessary delay.

The following study was designed to characterize the role of macular detachment in recovery of visual acuity, and, further, to determine the degree to which duration of detachment influences the final visual result.

MATERIALS AND METHODS

Nine hundred and fifty-three consecutive cases of primary rhegmatogenous retinal detachment, evaluated between January 1, 1975 and December 31, 1978, provided the data base for this study. There were 548 phakic cases (57.5%) and 405 aphakic cases (42.5%).

Demarcations with argon laser photocoagulation, xenon arc photocoagulation or transconjunctival cryopexy were performed in 58 cases (6.1%) with peripheral detachments. On the remaining cases, several types of scleral buckling procedures were performed, consisting of episcleral solid silicone rubber (81.3%), episcleral silicone sponge (6.9%), intrascleral solid silicone rubber (3.0%), and combinations of the preceding (2.7%). Cryopexy produced the chorioretinal reaction in all scleral buckling operations.

Visual acuities were recorded by trained technicians, utilizing Sloan or Snellen distance visual acuity charts, employing ± 0.50 diopter (D) and ± 1.00 D spheres over previous known corrections, in the same visual screening area under similar lighting conditions. To minimize the effect of duration of follow-up observations, final visual acuities were obtained, whenever possible, in the postoperative interval from three to six months. Acuities obtained later than six months were utilized only if patients had not been observed during the three to six month interval. Cycloplegic refractions were done routinely on patients with postoperative acuities less than 20/50.

The macula was defined clinically as a circular area approximately 1.5 mm in diameter, corresponding to the anatomic fovea or fovea centralis.[28] The preoperative macular status was ascertained by indirect ophthalmoscopy and confirmed by fundus biomicroscopy utilizing a three-mirror Goldmann contact lens. No attempt was made to characterize features, other than visual acuity, which differentiate patients with macular sparing from those with macular involvement.

Patients with postoperative visual acuities of 20/60 or less were routinely evaluated with a direct ophthalmoscope and fundus contact lens for macular pathology. Fluorescein angiography was not performed regularly.

Statistical analyses on postoperative visual acuity without regard to duration of macular detachment were limited to cases undergoing a single operation with a minimum follow-up period of three months, and consisted of those which were anatomically cured and those which were regarded as primary failures with persistent inoperable detachments. Patients with a follow-up time of less than three months were excluded. Also excluded were patients who experienced primary failures, but who underwent subsequent operations.

An effort was made to determine, as accurately as possible, the day of onset of macular symptoms. Durations of macular detachment were considered inaccurate and excluded from statistical analysis for the following reasons: (1) when impaired visual acuity had been discovered inadvertently; (2) when only a crude range of duration could be established; and (3) when a patient was regarded as a poor historian.

In the analysis of effect of duration of macular detachment on final visual acuity, several classes of patients were eliminated due to coexisting ocular pathology, which could affect adversely the final visual acuity. These included a history of congenital cataract surgery, nystagmus, amblyopia ex anopsia, retrolental fibroplasia, pars planitis, central corneal scarring, history of penetrating injury, senile cataract formation sufficient to obscure visualization of the central fundus, glaucoma with extensive disc cupping, retinal vascular occlusive disease, detachments due to macular holes, and macular scarring secondary to trauma, inflammatory disease, degenerative myopia, heredomacular degeneration or senile macular degeneration. Patients with preoperative macular cyst or hole formation and those with preoperative macular puckering were retained, since the two complications might be related to duration of detachment.

The single operative complication that resulted in exclusion of patients was subretinal hemorrhage in the macula (15 cases). Postoperatively, extensive vitreous opacities resulted in excluding two cases. Assuming the retina remained reattached, no other patient was excluded because of a postoperative complication (including anterior segment ischemia, angle closure glaucoma, open angle ocular hypertension, infection, or morphologic disturbances in the macula).

Data from phakic and aphakic eyes were combined, since several investigations have demonstrated similar visual recovery patterns in reattached cases.[2,6,13,17,19,22]

Statistical analyses were done using the SAS[29] software package with an IBM/168 Computer. Significance of differences among frequencies was determined by chi-squared analysis with Yates' continuity correction applied when appropriate. Linear regression analysis was accomplished with a general linear models procedure using the Proc GLM program. Non-linear regression was accomplished with the Proc N-LIN program. Given original estimates of the non-linear model, Proc N-LIN uses an iterative process to improve continually the estimates until the error sums of squares is minimized. Both linear regression and non-linear regression provide least square estimates of their parameters.

For both linear and non-linear regression analysis distance visual acuities were converted to a decimal notation to provide a linear scale for visual function (Table I). Extremely poor visual acuities of finger counting and hand motion or light perception arbitrarily were assigned values of 0.01 and 0.001, respectively.

TABLE I: CONVERSION OF SLOAN OR SNELLEN DISTANCE VISUAL ACUITIES TO DECIMAL NOTATION

DISTANCE VISUAL ACUITY	DECIMAL EQUIVALENT
20/20	1.00
20/25	0.80
20/30	0.67
20/40	0.50
20/50	0.40
20/60	0.33
20/70	0.29
20/80	0.25
20/100	0.20
20/125	0.16
20/160	0.12
20/200	0.10
15/200	0.075
10/200	0.050
5/200	0.025

RESULTS

PREOPERATIVE MACULAR STATUS

Nine hundred and fifty-three primary retinal detachments entered the study of which 70% included the macula (Table II). Opacities of the media or very flat detachments prevented determination of the macular status approximately 1% of the time. Macular sparing was not associated invariably with intact visual acuity, a situation explained by coexisting ocular pathology. Further, excellent vision was preserved in a small proportion of cases with obvious macular detachments (Table III). Nevertheless, differences in preoperative visual acuities between cases with macular sparing and those with macular involvement were highly significant ($P < 0.0001$).

SURGICAL RESULTS

After a single operative procedure, 738 cases (77.4%) were cured anatomically for a minimum of three months. Eighty-six cases (9.0%) represented primary failures and had no further surgery, usually due to inoperable

TABLE II: PREOPERATIVE MACULAR STATUS IN 953 PRIMARY RETINAL DETACHMENTS

MACULAR STATUS	NO CASES	PERCENT
Attached	283	29.7
Detached	662	69.5
Indeterminate	8	0.8

TABLE III: CORRELATION OF PREOPERATIVE MACULAR STATUS WITH INITIAL VISUAL ACUITY IN 936* PRIMARY RETINAL DETACHMENTS

PREOPERATIVE MACULAR STATUS	INITIAL VISUAL ACUITY					
	20/20–20/50		20/60–20/200		< 20/200	
	NO CASES	%	NO CASES	%	NO CASES	%
Attached	235	85.1	27	9.8	14	5.1
Detached	20	3.1	96	14.7	536	82.2
Indeterminate	3	37.5	2	25.0	3	37.5
			$P < 0.0001$			

*The initial visual acuity was not obtained in 17 cases.

massive periretinal proliferation, but occasionally because patients declined additional procedures. There were 93 patients (9.8%) who experienced primary surgical failures, but underwent secondary operations. An additional 36 cases (3.8%) were followed postoperatively for less than three months.

POSTOPERATIVE VISUAL RECOVERY

Of the 824 cases for which a single operation was performed, 27% had preoperative acuities of 20/50 or better. Postoperatively, 38% of this group, including failures, had acuities of 20/50 or better (Table IV).

A highly significant correlation ($P < 0.0001$) was found between final visual acuity and the surgical result (Table V). Postoperatively, there was a pronounced shift away from acuities less than 20/200, but only 42% of reattached cases achieved 20/20 to 20/50 acuity. Five percent of surgical failures maintained 20/20 to 20/50 acuity for at least three months, because the detachments remained limited to the periphery.

Macular detachment exhibited a strong negative influence on recovery of central vision (Table VI). Twenty percent of cases involving the macula regained 20/50 or better vision compared to 82% in which the macula was spared, a difference which was highly significant ($P < 0.0001$).

TABLE IV: COMPARISON OF PREOPERATIVE AND POSTOPERATIVE VISUAL ACUITIES IN 824 RETINAL DETACHMENTS HAVING ONE OPERATION

DETACHMENT STATUS	VISUAL ACUITY					
	20/20–20/50		20/60–20/200		< 20/200	
	NO CASES	%	NO CASES	%	NO CASES	%
Preoperative	221	26.8	103	12.5	500	60.7
Postoperative	317	38.5	281	34.1	226	27.4
			$P < 0.0001$			

TABLE V: CORRELATION OF SURGICAL RESULT WITH FINAL VISUAL ACUITY IN 824 RETINAL DETACHMENTS HAVING ONE OPERATION

POSTOPERATIVE RETINAL STATUS	FINAL VISUAL ACUITY					
	20/20–20/50		20/60–20/200		< 20/200	
	NO CASES	%	NO CASES	%	NO CASES	%
Attached	313	42.4	280	37.9	145	19.6
Detached	4	4.7	1	1.2	81	94.2
			$P < 0.0001$			

The preoperative visual acuity had a highly significant correlation with final acuity ($P < 0.0001$). Eighty-nine percent of the cases presenting with 20/20 to 20/50 acuity maintained that level of vision postoperatively. In contrast, 47% of the cases presenting with 20/60 to 20/200 acuity and only 15% of cases initially less than 20/200 recovered vision of 20/50 or better. Sixty-two percent of the cases with a final acuity of 20/20 to 20/50 were accounted for by the group with 20/20 to 20/50 acuity preoperatively (Table VII). In the group with an initial visual acuity range of 20/20 to 20/50, 9% dropped to the 20/60 to 20/200 range and another 3% fell below 20/200 postoperatively. Similarly, in the group with an initial visual acuity range of 20/60 to 20/200, 14% dropped below 20/200 following surgery.

DURATION OF MACULAR DETACHMENT

In this study, approximately one-third of the patients were able to provide adequate information regarding the onset of macular involvement. After excluding cases with pre-existing ocular disease, macular hemorrhage and vitreous opacities, there remained 205 patients, each with a primary retinal detachment, able to provide an accurate history, reattached with a single scleral buckling procedure, and followed for a minimum of three months. Including hospitalization time required for preoperative evaluations, most patients experienced macular detachments of relatively short duration. Forty-two percent were operated within 9 days of subjective symptoms,

TABLE VI: CORRELATION OF PREOPERATIVE MACULAR STATUS WITH FINAL VISUAL ACUITY IN 816* RETINAL DETACHMENTS HAVING ONE OPERATION

PREOPERATIVE MACULAR STATUS	FINAL VISUAL ACUITY					
	20/20–20/50		20/60–20/200		< 20/200	
	NO CASES	%	NO CASES	%	NO CASES	%
Attached	197	82.4	20	8.4	22	9.2
Detached	117	20.3	259	44.9	201	34.8
			$P < 0.0001$			

*The macular status was indeterminate in eight cases.

TABLE VII: CORRELATION OF INITIAL VISUAL ACUITY WITH FINAL VISUAL ACUITY IN 824 RETINAL DETACHMENTS HAVING ONE OPERATION

INITIAL VISUAL ACUITY	FINAL VISUAL ACUITY					
	20/20–20/50		20/60–20/200		< 20/200	
	NO CASES	%	NO CASES	%	NO CASES	%
20/20–20/50	196	88.7	19	8.6	6	2.7
20/60–20/200	48	46.6	41	39.8	14	13.6
< 20/200	73	14.6	221	44.2	206	41.2
			$P < 0.0001$			

77% within 19 days and 88% within 29 days. The remaining 12% were distributed over an additional 45 days (Fig 1).

Ninety-one percent (186/205) of the postoperative visual acuities were recorded during the interval from three to six months. Nineteen patients (9%) had their final acuities recorded from 7 to 30 months postoperatively. The mean observation period was four and one-half months for the entire group.

Fifty-three percent (46/87) of the cases operated within 9 days achieved 20/20 to 20/50 acuity, a proportion which diminished to 34% (24/70) of those operated from 10 through 19 days and to 29% (14/48) of those operated beyond 19 days. Macular involvement of 9 days or less was associated significantly more often with final acuities of 20/50 or better than durations of 10 through 19 days ($P < 0.05$) and durations of 20 days or more ($P < 0.05$). The frequencies of 20/20 to 20/50 acuity were not significantly different between durations of 10 through 19 days and 20 days or more ($P > 0.05$).

Only four patients (2%), all operated within five days of macular detachment, regained 20/20 acuity. Eleven cases (5.4%) recovered 20/25 acuity, but none after 21 days of macular detachment. Twelve cases (5.9%) recovered 20/30 acuity, but none after 19 days. Thirty cases (14.6%) recovered 20/40 acuity, but only two after 28 days. An additional 27 cases (13.2%) recovered 20/50 acuity, but only 2 after 21 days. Therefore, 84 cases (41%) regained a visual range of 20/20 to 20/50. The average visual acuity for the entire group of 205 patients was approximately 20/60.

Since more than three-fourths of the patients were operated within 19 days of macular detachment, a scatter plot, displaying every postoperative visual acuity with a conventional linear scale indicating duration, resulted in crowding of observations toward the lower end of the time scale (Fig 2). By visual inspection, it was impossible to determine a trend relating visual acuity to duration of macular detachment or to devise a line (or curve) which would be representative of the population. Linear regression analy-

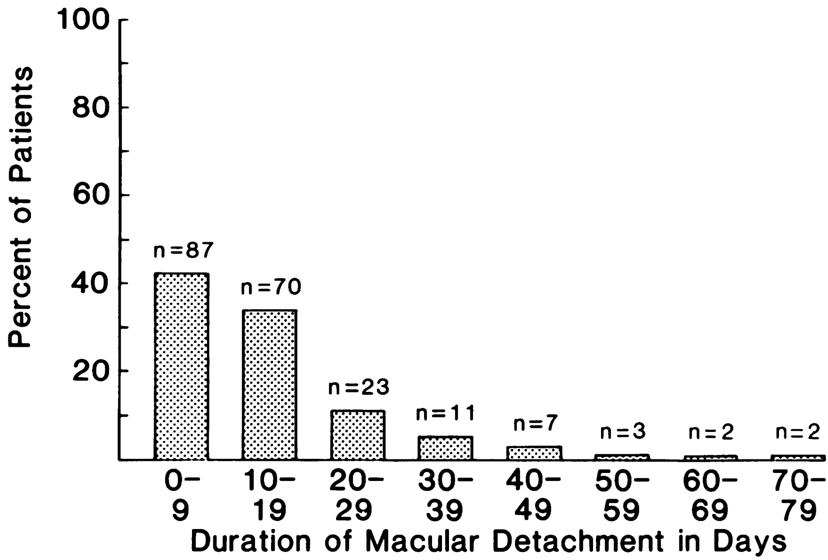

FIGURE 1
Frequency distributions of durations of macular involvement in patients with primary retinal detachment. (n = 205.)

sis indicated that a straight line did not describe adequately the trend in distribution of postoperative visual acuities.

When the observations were plotted on a semi-log graph, the downward trend in visual recovery with increasing duration was recognized (Fig 3). Although there was considerable scatter of the data, especially after about 12 days, the negative influence of increasing duration on visual recovery was emphasized by similarly plotting the means of the observations for each day (Fig 4).

When the mean observations were plotted on a conventional linear scale, the variation in the data was evident (Fig 5).

A non-linear regression model was designed to estimate the trend in visual recoveries, using duration as the only modifying factor (Fig 6). The r-square value of the mathematical model was 0.71. Therefore, 71% of the variation in final visual acuities observed in this study was explained by the effect of duration of macular detachment alone.

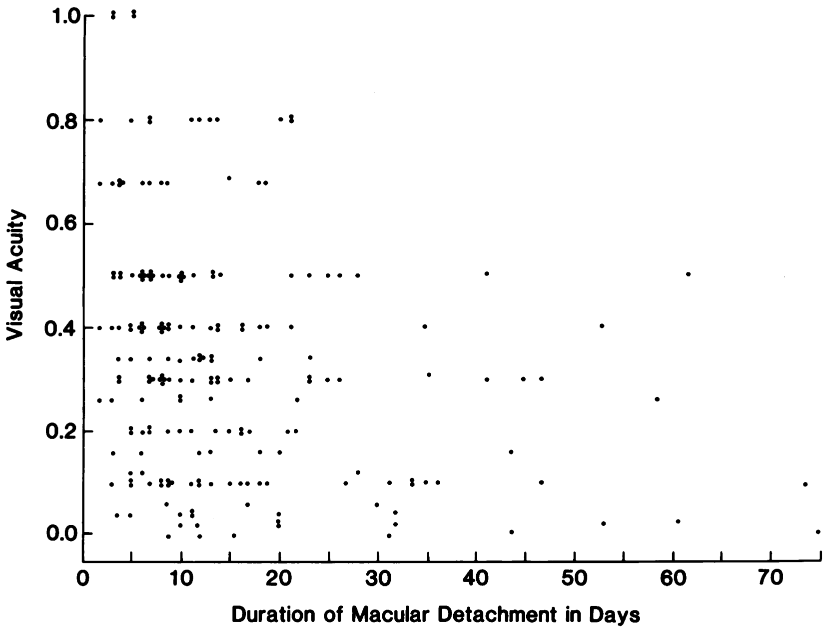

FIGURE 2
Linear scale graph of postoperative visual acuities results in crowding of observations. Relationship between visual acuity and duration cannot be represented by a straight line. (n = 205.) (See Table I for Conversion of Visual Acuity.)

The regression line can be expressed mathematically by the exponential equation: $y = ae^{-bx}$, where

y = postoperative visual acuity,
a = .44 (the calculated y intercept),
e = 2.718 (base of natural logs),
b = $-.022$ (calculated constant exponent),
x = duration in days.

The negative value for the constant exponent indicates a progressively declining value in visual recovery with increasing duration of macular detachment, but reaching the zero point only after an infinitely long period of time.

For each day of duration, the model also yielded limits of one standard deviation above and below the mean for single observations (Fig 7). By five days of duration, visual recovery averaged 20/50. By 13 days of duration, the average acuity declined to 20/60. Visual recoveries averaged 20/70 at 20

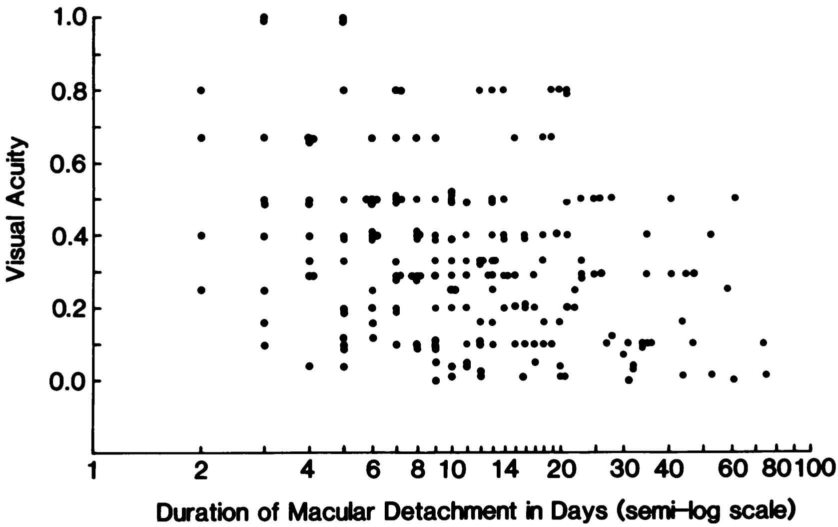

FIGURE 3
Semi-log graph of postoperative visual acuities overcomes crowding of observations and indicates decreasing visual recovery with increasing duration. (n = 205.)

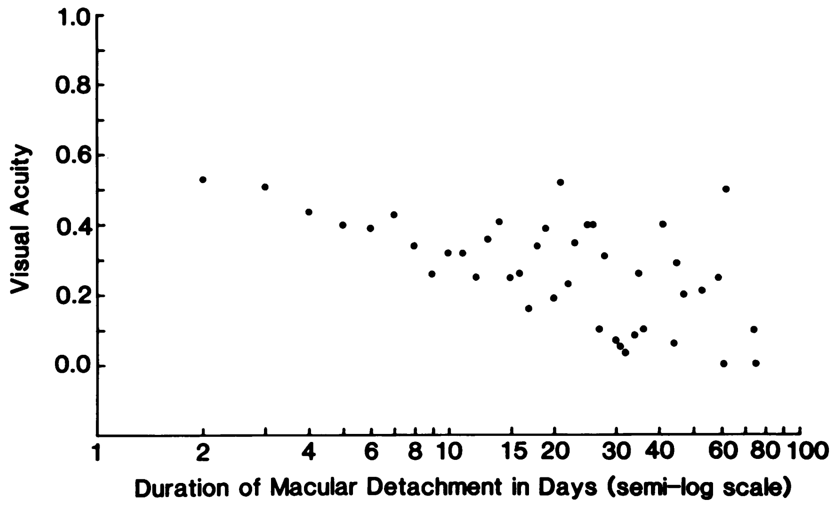

FIGURE 4
Semi-log graph of means of postoperative visual acuities emphasizes decreasing visual recovery with increasing duration. (n = 205.)

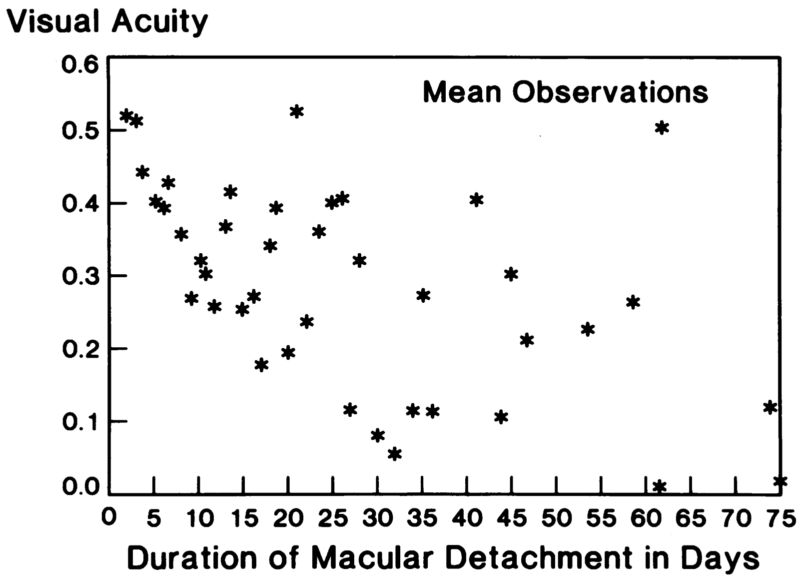

FIGURE 5
Linear scale graph of means of postoperative visual acuities emphasizes variation in data. (n = 205.)

days, 20/80 at 27 days, 20/100 at 37 days, 20/125 at 47 days, 20/160 at 58 days and 20/200 at 69 days.

Given the duration of macular detachment, the estimated final visual acuity for any individual in this study can be calculated from the preceding equation. Alternatively, the postoperative visual range can be estimated with 67% accuracy for an individual case by utilizing Figure 7 as a nomogram.

POSTOPERATIVE MACULAR CHANGES

Visual acuities of less than 20/50 were recorded in 47% (41/87) of patients with durations of macular detachment of 9 days or less, in 66% (46/70) of patients with durations of 10 to 19 days, and in 71% (34/48) of patients with durations of 20 days or more (Table VIII). Some form of macular pathology was observed in 45% of cases with final acuities of less than 20/50. Macular pucker occurred most frequently (26%), but was not related to duration of detachment ($P > 0.05$). Macular pigmentation occurred in 13% of the cases, but was not related to duration of detachment ($P > 0.05$). Six percent

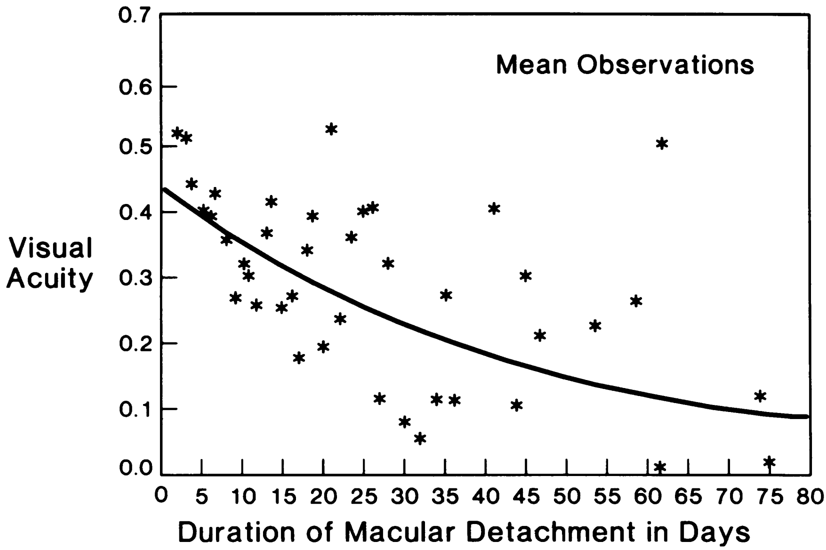

FIGURE 6
Non-linear regression curve superimposed on means of postoperative visual acuities. Equation $y = ae^{-bx}$ describes negative exponential relationship between visual recovery and duration of macular detachment. (n = 205.)

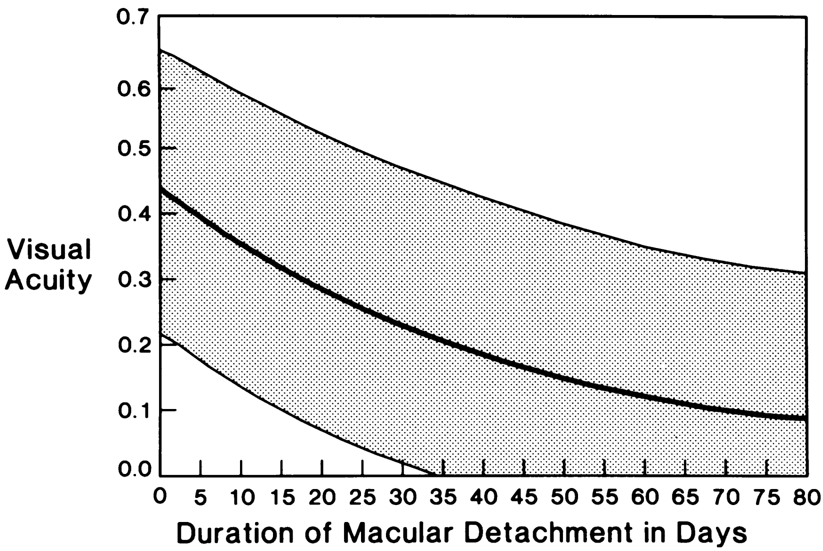

FIGURE 7
Non-linear regression curve ± one standard deviation indicates expected range of visual recovery for durations of macular detachment of 1 to 80 days for individual patients.

TABLE VIII: MACULAR CHANGES IN 121 PATIENTS WITH DETACHMENTS OF KNOWN DURATION AND FINAL VISUAL ACUITIES OF LESS THAN 20/50

DURATION IN DAYS	POSTOPERATIVE MACULAR ALTERATION							
	PUCKER		PIGMENTATION		CYST/HOLE		NONE	
	NO CASES	%	NO CASES	%	NO CASES	%	NO CASES	%
0–9	11	26.8	5	12.2	3	7.3	22	53.7
10–19	11	23.9	4	8.7	2*	4.3	29	63.0
> 19	9	26.5	7	20.6	3	8.8	15	44.1

*One case of macular cyst was diagnosed preoperatively.

of cases appeared to have macular cysts or holes, one of which was observed preoperatively in the 10 to 19 day duration group.

The 31 cases of macular pucker had visual acuities ranging from 20/60 to hand motion with a mean of 20/160. The 16 cases of macular pigmentation had visual acuities ranging from 20/60 to finger counting with a mean of approximately 20/125. The eight cases of macular cyst or hole had visual acuities ranging from 20/70 to finger counting with a mean of approximately 20/160.

DISCUSSION

In 1934 Dunnington and Macnie[1] observed that once the macula had become involved in the detachment process, reattachment of the retina failed to restore central visual acuity. Reese[30] (1937), later reviewing the data of Dunnington and Macnie, wrote that 38% of successfully operated cases that had been detached for less than one month recovered at least 20/30 acuity, compared to 26% of cases detached over one month. He concluded that duration of detachment was a factor in determining the final visual result.

Reporting the collaborative results of numerous retinal surgeons in 1952, Hughes[27] found that detachment of the macula did not necessarily indicate a poor visual prognosis, since nearly one-third of patients with preoperative acuities of 20/200 or worse recovered to 20/40 or better. He suggested the ultimate prognosis for at least 20/40 vision was unaffected by a history of detachment less than six months old.

In 1963 Norton[2] determined that poor visual acuity was explained by three principal factors: vitreous traction, macular detachment and duration of macular detachment. When the macula was detached only 38% of cases recovered 20/50 acuity or better, compared to 84% in cases sparing the macula. While patients with durations exceeding two months had a much poorer prognosis, the visual results were similar for those operated before two weeks and from two to eight weeks.

Jay[18] (1965) concluded that as long as the macula had not been detached longer than two months, the final visual acuity, which averaged 6/18 (20/60), was not dependent on duration. After two months, the final acuity was dependent on duration, with very little recovery of macular function observed in cases exceeding six months.

In contrast, Hudson[7] (1968) observed that surgery within two weeks of macular detachment provided better visual results, with reattached cases averaging approximately 20/60 acuity. After two weeks, there was little influence of duration on final acuity, averaging about 20/120 even in cases beyond six months.

If cryopexy had produced the chorioretinal reaction in eyes with macular detachment, Hilton et al.[8] (1969) found that 60% recovered at least 20/50 acuity, when the duration was less than two weeks, compared with 38% for durations of two to eight weeks and 25% for durations exceeding two months.

Jacklin[12] (1972) reported that 37% of macular detachment cases recovered at least 20/50 acuity. No data were presented to support his contention that duration of macular involvement determined the degree of recovery.

Charamis and Theodossiadis[11] (1972) found less favorable results when macular detachments exceeded one month in duration, but observed no significant variations in final visual acuities for durations ranging from 15 to 30 days.

Davies[20] (1972) concluded that the final visual acuity was dependent on duration of macular detachment and development of recognizable postoperative complications, such as macular hemorrhage, choroidal hemorrhage, uveitis, macular pigmentation and macular pucker. The highest rate of visual recovery occurred in detachments with durations less than seven days, after which there was only a gradual decline for six months.

Cairns[31] (1973) found that 20% of cases with macular involvement achieved at least 6/18 (20/60) acuity compared with 71% of cases with macular sparing. In the macular detachment group operated within seven days there was a 38% recovery to at least 6/18 acuity, compared with 33% and 16% for those operated at one to four weeks and one to six months, respectively.

In cases of macular detachment operated during the first week, Gundry and Davies[25,26] (1974) showed a decline in final vision from day one onward. After the first week the advantage of early surgery was less evident, until the stage of six months, when there appeared to be a dramatic fall in visual recovery. Improper construction of the graphic model, in which the time scale was arbitrarily non-linear, resulted in erroneous interpretation of the data. There was no basic unit of time. Durations of 0 to 7 days, 14 to 28 days, 1 to 3 months, 3 to 6 months, and anything beyond 6 months all were assigned equal intervals on the abscissa. If a linear or semi-log scale had been employed, the apparent precipitous fall in visual recovery would have been eliminated and replaced by gradually declining values for increasing durations.

In a study of 179 eyes, Grupposo[15] (1975) found that not until after eight weeks of macular detachment was there a significant reduction in recovery of macular function. The conclusion may have been influenced by the division of visual acuity into broad classes (rather than using a linear scale) and comparison of proportions of eyes regaining 20/70 acuity or better.

Neither length of follow-up nor the postoperative interval during which final acuities were obtained was reported. Further, although reported in 1975, all the cases had been operated 10 to 16 years earlier, when other surgical methods, such as lamellar scleral dissection and partial penetrating diathermy, were conventional.

Davidorf et al[22] (1975) reported that duration of macular detachment made little difference in visual acuity until after one month. Included were cases with pre-existing ocular pathology, which could have influenced visual recovery adversely. Patients with preoperative acuities of better than 20/400 were excluded, under the assumption that such cases had only partial macular involvement. Average visual recoveries were displayed graphically with non-linear scales for both visual acuity and duration of detachment, which resulted in an artifactitious slope of the curve. Apparently, most of the final visual acuities were obtained from referring physicians, a nonstandardized method which must be regarded with suspicion.

Kreissig[10] (1977) identified four factors influencing postoperative macular functions: extent and height of macular involvement, duration of macular detachment, age of patient, and degree of myopia. Visual recovery in cases involving the macula was optimal with durations of seven days or less. Macular detachments lasting one to two weeks had no better prognosis than those lasting from two weeks to one year, beyond which there appeared to be a further decrease in visual recovery.

Noting numerous factors which could affect the final visual result, Marquez[21] (1979) indicated that early detachment surgery, especially in cases of macular sparing, resulted in a better prognosis. Visual acuity recovered up to 0.40 (20/50) with durations of macular detachment less than two weeks. Visual recovery declined to 0.15 (approximately 20/125) with durations of two weeks to six months and to 0.10 (20/200) after six months.

Tani et al[6] (1975) reported that 41% of cases with macular detachments less than one month in duration recovered 20/50 or better acuity compared with 28% of cases with durations exceeding one month.

Paralleling the recovery patterns in visual acuity are alterations in other psychophysical measurements. Retinal sensitivity, determined by static perimetry, diminishes in proportion to duration of macular detachment.[10,32-34] Color discrimination, measured by the Farnsworth-Munsell 100 hue test, decreases with increasing duration of detachment.[32,33] The Haidinger phenomenon is impaired progressively by detachments of longer duration.[34] Abnormalities in Amsler grid responses have been recorded in up to 85% of reattached cases, even in eyes with visual acuity of

5/5 (20/20).[35] Amsler grid defects have been correlated with extent or height, as well as duration, of macular detachment.[10,34]

Four principal weaknesses in design recur among the foregoing studies: (1) a non-linear scale for visual acuity; (2) a non-linear scale for duration of detachment; (3) variation in time of recording postoperative acuities; and (4) the assumption that all patients provide accurate histories establishing the onset of macular symptoms.

Conversion of Snellen or Sloan notations into decimal equivalents avoids excessively long (or arbitrarily divided) scales and the need to combine various acuities into broad classes, such as 20/60 to 20/200. However, difficulties will remain with acuity notations of finger counting, hand motion or light perception. A semi-log graph legitimately overcomes the crowding phenomenon encountered when one of the scales, such as duration, is excessively long and most of the observations are located at one of the extremes.

In this study, two-thirds of the patients were judged to be unable to provide accurate histories regarding the onset of macular symptoms. Many patients, who suddenly discovered impaired central vision by inadvertently occluding the uninvolved eye, were excluded. Patients for whom only a crude range of duration could be estimated were excluded. Typical of this problem was the recently aphakic individual who had not received a corrective lens and who apparently had developed a retinal detachment between consecutive visits to the primary ophthalmologist. Many patients simply were poor historians. It was axiomatic that histories became progressively vague and unreliable with detachments of increasing duration. The factors of improper graphic display of data and inclusion of data from unreliable patients largely have been responsible for the variation in conclusions about the effect of duration of detachment on visual recovery.

This study indicates that visual recovery, in response to increasing duration of detachment, declines in exponential fashion, similar to the decay curve of a radioactive material. Seventy-one percent of the variation in visual acuity was explained by duration of macular detachment alone. Assuming the duration to be known and patient selection similar to the manner described in this study, the final visual acuity can be estimated by the equation: $y = ae^{-bx}$. Alternatively, there is a 67% chance that the final visual acuity for any individual patient will fall within the shaded area in Figure 7, which can be used as a nomogram. However, the mean visual acuity obtained from several detachment patients, all having the same duration, will approach the value represented by the corresponding point on the regression line.

In this study, 29% of the variation in visual recovery was attributed to unknown factors, which probably include pre-existing ocular disease, patient age, refractive status, type of detachment, preretinal membrane formation, operative complications, postoperative complications, macular pathology and length of follow-up observations. Following successful detachment surgery, visual acuity may continue to improve for six months to five years.[9,14,25,26,32,33] The majority of cases have stable acuity three to six months postoperatively.[10,11,22,32,33,35] Declining vision occurs in a small percentage of reattached cases, usually from cataract formation, macular pucker or senile macular degeneration.[9,11,18,22] Utilizing a multiple regression model, Kaufman[19] found no significant correlation between final visual acuity and length of follow-up. However, a study of patients recalled 10 to 39 years after surgery revealed 44% with visual acuity worse than at discharge due to cataracts and macular degeneration.[36] The potential effect of length of follow-up on final acuity was minimized in the current study. While the mean observation period of four and one-half months may seem modest, 90% of the visual acuities were obtained during a three month postoperative interval.

Attention to surgical detail and avoidance of complications, such as choroidal hemorrhage, will enhance visual recovery. Likewise, careful observation during the immediate postoperative phase will permit recognition and appropriate treatment of vision threatening problems, such as angle closure glaucoma, anterior segment ischemia and severe infections. It should be obvious that meticulous postoperative refractions with attention to changes in axial length of the globe and corneal curvature will improve late visual results.[14,37-41] Nevertheless, the simple expedient of refraction often is neglected.

A high proportion of cases with poor visual recovery can be explained by morphologic changes of the retina, consisting predominantly of preretinal membrane formation (macular pucker), macular cysts, cystoid macular edema, subretinal pigment migration and retinal pigment epithelial atrophy.[9,18,23,24,30,42-48] Fundus contact lens examination and fluorescein angiography may be required to detect subtle changes.

Gross retinal pigment epithelial atrophy has been attributed to long standing macular detachment.[11,36] Cystoid macular edema is not related to duration of detachment.[47] The effect of retinal pigment epithelial fallout is disputed, but since that complication results from a surgical maneuver, there is no correlation with duration of preoperative detachment.[49-52]

Among the 205 patients with detachments of known duration, 59% failed to recover visual acuity better than 20/60. Approximately half of those patients were found to have macular pathology in the form of macular pucker, macular pigmentation, or degenerative cyst or hole formation. Since patients with visual acuities of at least 20/50 were not subjected to the same ophthalmoscopic examinations, it is likely that milder forms of preretinal membrane formation (surface wrinkling retinopathy) were undetected.[53,54] Therefore, an accurate estimate of the incidence of macular pucker for the entire group of patients cannot be established. It is possible that some of the cases diagnosed as macular cysts or holes actually represented cystoid macular edema, a differentiation which would have been improved by regularly obtaining fundus fluorescein angiography.

Experimental detachments in owl monkeys produce cystoid spaces within the retina and progressive degeneration of outer receptor segments.[55] Both changes are reversed by retinal reattachment.[56] The preceding observations have led several investigators to invoke the possibility that faulty realignment of receptor cells might explain impaired visual function in the absence of grossly visible retinal pathology.[9,17,23,24,32,33] Gradual realignment of receptors could account for some cases of slowly improving visual acuity.[57] Fitzgerald et al[58] have demonstrated corresponding improvements in Stiles-Crawford function, Snellen acuity and interferometric acuity after detachment surgery, although the importance of their observations remains uncertain.

SUMMARY

Nine hundred and fifty-three primary retinal detachments were analyzed to establish the effects of macular detachment on final visual acuity. Nearly 90% of cases with preoperative acuities of 20/20 to 20/50 maintained the same level of vision postoperatively. Over 80% of cases with macular sparing achieved 20/50 acuity or better, compared with 20% of cases with macular involvement. Two percent of patients with macular detachment of known duration regained 20/20 acuity. Similar to several previous reports, the overall visual results in this study were disappointing. Forty-two percent of all reattached cases recorded at least 20/50 acuity.

After macular involvement occurs, duration of macular detachment becomes the most important factor in determining final visual acuity. In this study, duration of macular detachment alone accounted for 71% of the variation in final visual acuities. Clearly, the macula does not fail to recover function after a specific time limit. Similarly, there is no duration beyond which visual acuity is lost precipitously. Instead, visual recovery behaves as a function of a biological system, declining rapidly during the initial stages of the detachment and more slowly as the detachment becomes chronic. The relationship between visual acuity and duration of macular

detachment is analogous to the decay curve of a radioactive material and can be expressed by the exponential equation: $y = ae^{-bx}$.

Given a detachment of known duration, the estimated final acuity can be derived from the preceding equation. The graphic display of the non-linear regression curve and limits for one standard deviation above and below the mean can be used as a nomogram to estimate the likely postoperative visual range for individual patients.

Few of the numerous factors affecting visual acuity in retinal detachment disease are subject to regulation. The time a macula is permitted to remain detached is an exception. Every reasonable effort should be made to minimize duration of macular involvement. There is no excuse for unnecessary delay of detachment surgery, whether for the convenience of the patient, surgeon, anesthesiologist or operating room schedule.

Since visual decline is a continuous process, there are no definite intervals when surgery is more or less advisable. Emergency status probably should be assigned to patients with macular symptoms of recent onset. In this study, no patient regained 20/20 vision with a macular detachment exceeding five days, a time when an average of 20/50 acuity is anticipated. Patients with macular detachments of longer duration still should be regarded with urgency. After 5 days, approximately one line of vision will be lost for each additional 7 days until 27 days. Beyond 4 weeks one line of vision will be lost for each additional 10 to 11 days of macular detachment, at least until approximately 70 days, when 20/200 will be the average visual recovery.

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